Exam in power electronics 2016-08-17

Means of assistance:	Calculator	
Grades:	20-30 p:	3
	31-40 p:	4
	41-50 p:	5
In total	5 exercises	

1 The four quadrant DC-DC converter

a) Draw a four quadrant DC DC converter with a three phase diode rectifier connected to the power grid. The Dc link capacitor and protection against too high inrush currents should be included in the drawing. The transistors are of IGBT-type. (1 p.)

b) The three-phase grid, to which the three phase diode rectifier is connected, has the line-to-line voltage 400 V_{rms} at 50 Hz. Calculate the dc output voltage and the maximum dc link voltage from the rectifier. (1 p.)

c) Calculate the rms-current and the average current through one rectifying diode (see figure 1). Calculate the rectifier diode losses. The diode threshold voltage is 1.1 V and the differential resistance is 2.0 mohm. (2 p.)

d) Calculate the IGBT component losses of each IGBT in the four quadrant converter.
The duty cycle of the converter is 80%. The inductance of the four quadrant converter load is high. The switching frequency is 2 kHz.
The threshold voltage of the IGBT transistor equals 1.2 V and its differential resistance equals 1.0 mohm. The turn-on loss of the IGBT transistor equals 60 mJ and its turn-off loss equals 80 mJ. These turn-on and turn-off losses are nominal values at 900 V dclink voltage and 180 A turn-on and turn-off current.
The threshold voltage of the IGBT diode equals 1.0 V and the differential resistance of this diode equals 10 mohm. The IGBT diode turn-on can be neglected and its turn-off losses equals 25 mJ, at 900 V dclink voltage and 180 A. (4 p.)

e) Which is the junction temperature of the IGBT transistor and of the IGBT diode, and which is the junction temperature of the rectifying diodes?
The thermal resistance of the heatsink equals 0.024 K/W?
The thermal resistance of the IGBT transistor equals 0.07 K/W?
The thermal resistance of the IGBT diode equals 0.16 K/W?
The thermal resistance of the rectifier diode equals 0.14 K/W?
The ambient temperature is 35 ^{o}C.
The rectifier diodes and the four quadrant converter IGBTs share the heatsink. (2 p.)

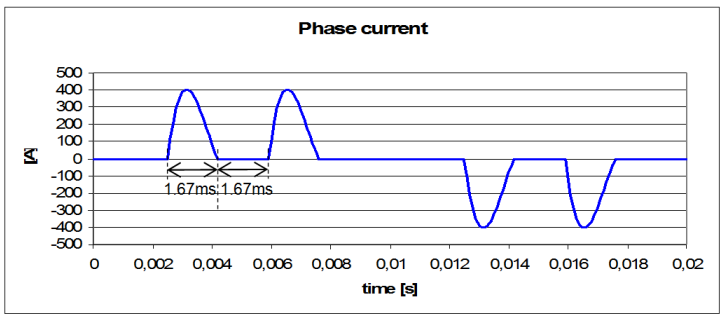


Figure 1

2 Snubbers

a) Draw an IGBTequipped step down chopper (buck converter) with an RCD snubber. The dclink voltage on the supply side is 200V and the load voltage is 150 V. Give a detailed description of how the RCD charge-discharge snubber should operate. Explain why the snubbers are needed (2 p.)

b) Calculate the snubber capacitor for the commutation time 0.015 ms. The load current is 10 A, assumed constant during the commutation. Calculate the snubber resistor so the discharge time (3 time constants) of the snubber capacitor is less than the IGBT on state time. The switch frequency is 2 kHz (4 p.)

c) Draw the main circuit of a flyback converter. The circuit should include DM-filter (differential mode) ,CM (common mode) filter, rectifier, dc link capacitors, alternative connection for voltage doubling connection, switch transformer (one primary and one secondary winding is enough), switch transistor, flyback diode and a simple output filter, The circuit should also include snubbers. (2 p.)

d) Describe, in detail, the operation of the flyback converter snubbers you have used. Describe in detail how the current is flowing in the snubber and the voltages n the snubber (2 p.)

3 Three phase system and 4QC

a) A symmetric three phase voltage:

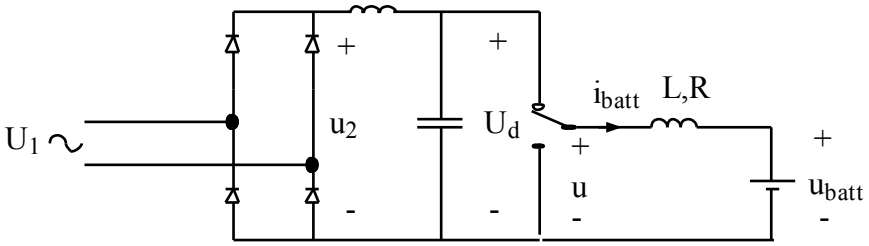
$$\begin{cases} e_a = \hat{e} \cdot \cos(\omega \cdot t) \\ e_b = \hat{e} \cdot \cos\left(\omega \cdot t - \frac{2\pi}{3}\right) \\ e_c = \hat{e} \cdot \cos\left(\omega \cdot t - \frac{4\pi}{3}\right) \end{cases}$$

Show that these voltages form a rotating vector with constant length and constant speed in the complex (α,β) frame. (5 p.)

b) In a 4Q DC/DC converter using PWM bipolar voltage switching, the bridge load consist of a constant voltage E (e.g. the back emf of a dc-motor) and an inductor L_a, the inductor resistance can be neglected. The switching frequency is f_{sw}, and the DC-link voltage is U_{dc}. Calculate the maximum peak-to-peak load current ripple expressed in U_{dc} L_a and f_{sw}. (5 p.)

4 Rectifier & DC/DC Converter

A battery charger is supplied from a symmetrical **single** phase system. A dc voltage is created by a two pulse diode bridge and a 2-quadrant dc-converter is used for the charge current control.



Data: U_{1rms} = the phase-voltage rms value = 220 V. The switching frequency is f = 4 kHz. L = 4 mH and R=0 Ohms. U_{batt} = 100 V and is approximated to be independent of the charge current.

a) What dc link voltage U_d will you get I) when the charging current is zero and II) when the charging current is non-zero with a perfectly smooth rectified current ? (2p)

b) Start with the electrical equation for the load and derive a suitable current control algorithm, giving all approximations you use. (4p)

c) Draw a current step from 0 A till 10 A in the load current. The modulating wave (u_m), the voltage reference (u*), the output voltage (u) and current (i_{batt}) must be shown. Indicate the sampling frequency you use in relation to the switching frequency. (4p)

5 A PM Machine

A permanently magnetized synchronous machine with $L_{sy}>L_{sx}$ is used as a traction motor in an electric vehicle.

a) Write the torque expression in rotor coordinates, and describe your interpretation of the terms in the expression, and how they relate to the rotor geometry and magnetization.(4p)

b) Explain, in a qualitative sense, what is the best locus for the stator current vector to minimize the amount of current needed for torque production. (3p)

c) Explain the restrictions to the stator current loci that are imposed when the need for stator voltage is higher than the maximum available voltage. (3p)